

NATIONAL EXAMS DECEMBER 2010

98-Pet-A2, Petroleum Reservoir Fluids

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.
2. Candidates may use one of two calculators, the Casio or Sharp approved models. This is a Closed Book exam; however candidates are permitted to bring in one (1) aid sheet, 8.5x11" (both sides) which can contain notes and formulae.
3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
4. All questions are of equal value (as indicated).

Question 1 (20 marks):

- (a) Define fugacity, fugacity coefficient, activity coefficient, vapor pressure and partial pressure (4)
- (b) Define an ideal solution using an equation involving fugacities and mole fractions. (4)
- (c) Write down the expression for thermodynamic equilibrium normally known as Raoult's law. (4)
- (d) Can you use Raoult's law to describe the behavior of hydrocarbon fluids at low pressures? Please detail your reasoning. (4)
- (e) Can you use Raoult's law to describe high pressure / high temperature phenomena of interest in hydrocarbon processing such as critical points? Explain your answer (4)

Question 2 (20 marks):

Hydrocarbon mixture PT Envelope

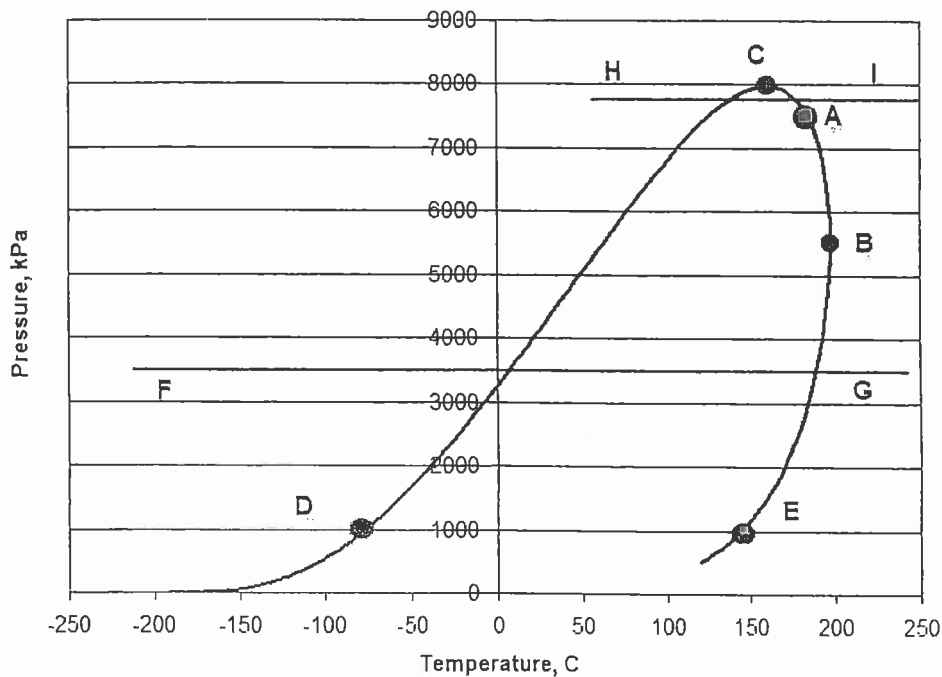


Figure 1. Hydrocarbon mixture Pressure/Temperature (PT) envelope

Using figure 1 as a reference please answer the following questions. Note that the physical properties of the vapor and liquid phases are *identical* at point A.

- (a) Define points A, B and C and explain their significance from a physical point of view. (4)
- (b) What is the name of the curve defined by points DCA? (2)
- (c) What is the name of the curve defined by points EBA? (2)
- (d) Describe the phase behavior of this fluid as it is heated from point F to point G in detail. (4)
- (e) Sketch the vapor fraction as a function of temperature when the fluid is heated from point H to point I. (4)
- (f) Using the figure above sketch a 25% quality PT curve and a 75% quality curve. Assume the quality is defined in mol percent. (4)

Question 3 (20 marks):

Cubic equations of state are commonly used for the modeling of hydrocarbon systems. One of the most popular cubic equations of state using in process and reservoir simulation is the Peng-Robinson equation of state. A common way of defining the Peng-Robinson equation of state is given by equations 1, 2, 3 and 4.

$$P = \frac{RT}{v-b} - \frac{a}{v(v+b)+b(v-b)} \quad 1$$

$$a = \sum_{i=1}^{nc} \sum_{j=1}^{nc} \sqrt{a_i a_j} x_i x_j (1 - k_{ij}) \quad 2$$

$$b = \sum_{i=1}^{nc} b_i x_i \quad 3$$

$$a_i = a_{ci} \alpha_i(T) \quad 4$$

- Define the symbols a, b, i, v, R, T, P, x_i and k_{ij} . (2)
- Sketch a pressure / volume diagram for a pure fluid showing the gas and liquid saturation curves and the critical isotherm. (4)
- Write the derivatives of pressure with respect to volume that define the critical point conditions for a pure fluid. (2)
- Explain how by using the critical point conditions the Peng-Robinson pure component constants a_{ci} and b_i can be calculated. (4)
- Explain why the term $\alpha_i(T)$ is important and how can it be determined. (4)
- Explain why the term k_{ij} is important and how it can be determined. (4)

Question 4 (20 marks):

The a and b constants for the Peng-Robinson equation of state for water are equal to:

$$\begin{aligned} a &= 972.76 && \text{kPa.m}^6/\text{kmol}^2 \\ b &= 0.018979 && \text{m}^3/\text{kmol} \\ R &= 8.3144 && \text{kJ/kmol.K} \end{aligned}$$

- Calculate the molar volume of liquid water at 25 C and 1 atmosphere (4)
- Based on the results you obtained in (a) calculate the density of liquid water in kg/m^3 and the compressibility factor. (4)
- Comment on the reliability of the Peng-Robinson equation of state when used for the calculation of volumetric properties of water. (4)
- What is the expected error when using the Peng-Robinson equation of state for the calculation of volumetric properties of hydrocarbons in liquid phase? (4)
- If the saturation pressure of water at 25 C as predicted by the Peng-Robinson equation of state is equal to 2.7 kPa estimate the amount of water present in air saturated with water at 25 C and 1 atmosphere. (4)

Question 5 (20 marks):

A useful simplification when dealing with oil / water systems is to assume that oil and water are completely immiscible. Use n-octane as a prototype for the oil and the vapor pressure data presented in table 1.

T	Water	n-Octane
C	kPa	kPa
10	1.18	0.83
20	2.27	1.51
30	4.14	2.61
40	7.23	4.34
50	12.14	6.95
60	19.69	10.78
70	30.91	16.20
80	47.11	23.71
90	69.93	33.84

- (a) What is the bubble pressure for a mixture containing 50% oil and 50% water (in molar basis) at 50 C? (4)
- (b) What is the bubble temperature for a mixture containing 25% oil and 75% water (in molar basis) at 50 kPa? (4)
- (c) What the vapor composition for the fluid at its bubble point is as calculated in (b)? (4)
- (d) What is the dew pressure for a mixture containing 50% oil and 50% water (in molar basis) at 50 C? (4)
- (e) What the liquid phase composition for the fluid at its dew pressure is as calculated in (d)? (4)

Question 6 (20 marks):

- (a) Define GOR (4)
- (b) Describe a differential liberation test. (4)
- (c) Describe a constant volume expansion test., (4)
- (d) Organize the following hydrocarbon species in increasing order of solubility in water at 25 C and 1 atmosphere: paraffins, olefins, naphthenes and aromatics (4)
- (e) Describe qualitatively what happens to the solubility of natural gas in water when NaCl is added to the water phase. (4)

TOTAL MARKS: 100

---- END OF EXAMINATION ----